“Futures” of Space Technology
“Frontiers of The Responsibly Imaginable”

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Space Technology Issues/Metrics

- Bandwidth
- Resolution/Aperture
- Propulsion
- Power/Energy Storage
- Space Access
- Radiation Protection
- Size/Weight
- Sensitivity
- Machine Intelligence
- Affordability
- New/Different "Observables"
- 'Protection"
- Reliability

THE KEY TECHNOLOGIES
(highly synergistic / at the frontiers of the small / in a "feeding frenzy" off each other)

- **IT (comms/computing/sensors/electronics/machine intelligence)**
- **Bio (genomics/molecular biology/designer life forms)**
- **Nano (coatings/barriers/computers/sensors/materials/ "assemblers")**
- **Energetics (HEDM (various)/revol. solar/biomass/explosives/propellants/storage)**
- **Quantum [crypto/computing/sensors/optics/Electronics]**

Ongoing Space Technology "Revolutions"

- **Micro/Nano Sats**

  - Far lower launch costs [value/lb vs. $/lb]

  - Far greater launch "flexibility/ubiquity"

  - Toward "Everymans" Capability" [$45K fab and ride - Utah Co.,Tokyo Univ.]

  - Co-operative Conops/"Formation Flying" for Aperture [Multitudinous enabling approaches/technologies]

Ongoing Revolutions [Cont.]

- **Nano Sensors,Orders of Magnitude Improvements in: sensitivity,bandwidth,size [red.],Cost [red.] - i.e. E-6 degree IR sensit.**
- **Energetics:**

- Thermal Diodes [20%-30% Direct Conversion]

- Zeolite H2/Methanol Storage [Ionomers]

- CNT Flywheels, MIT MEMS Rockets

- LENR's,SMES/CNT Magnets

- HEDM [Various]

- Tethers,Room Temp. S-C

Ongoing Revolutions [Cont.]

- **Materials:**

- SWCNT/NNT

- Gossamer Membranes Etc./"Light Buckets"

- In-space e-beam based free form fab

- Syntactic foams,Str. Amorphous metals,micro-structured materials,brilliant materials

- **Computing /Comms.**

- Optical Comms in-the-large

- Bio/optical/Quantum/CNT/Molecular Computing

Potential CNT Applications

- Overall [structural/radiator] weight reductions order of 3 to 8
- Flywheels
- Mag. Sail
- [Better] Tethers
- Ultra Capacitor
- Sensors/Computing/Electronics - 2-4 orders of magnitude improvements…
- High/Room Temperature S-C
- Extreme multi-functionality

Carbon Nano-Tubes…….

- **A “One-Stop Shopping Brilliant Material”?**

- Nascent/Coincident Sensing,Petaflop LOW ENERGY Computing,EM Actuation,[H2,E-M] Energy Storage,Huge strength-to-weight,Anti-Radar?

Membrane Structures

- **Lightweight/Deployable/Inflatable/Rigidizable [Including Struts/Trusses]**
- **100M to 1000M Apertures [eventually]**
- **Multitudinous Applications [“sails”,antennas,”light buckets”,solar arrays,planet/life finders”,concentrators, mirrors,lenses,radiators,sunshades….]**
- **Distributed actuation/power/processing/sensing**

Ongoing Revolutions [Concluded]

- **Misc.**

- Nano optics [1/100th size/weight/cost]

- Nanobots

- Machine Intelligence

- Insitu robotic repair/refueling

- “Revolutionary Rocket”

AI (AND BEYOND) COMPUTING

Human Brain Characteristics/Capabilities

- **100 billion neurons**
- **100 trillion connections**
- **200 calculations/second, (slow) speed of neural circuitry**
- **20 million billion calculations/second**
- **Excellent at (parallel-computing) pattern recognition, “poor” at sequential thinking**
- **Operates via “random tries”**

Machine Capabilities

- **Currently,200,000 billion calculations/second**
- **By 2012, 20 million billion is available (by 2025, on a PC)**
- **By 2030, PC has collective computing power of a town full of human minds**

Machine Intelligence

- **Approaches:**
  - **Experiential - Behavior Based/'learning" (neural nets/other "Soft Computing")**
  - **Nano-section/replicate brain in Silicon**
  - **"Emergence"**
- **Should produce Artificial/Cyber "life" which will possibly-to-probably be sentient but will not be anthropomorphic**

“Beyond” NANO - Quantum Synopsis - Quantum Technology

- **Largely enabled by/synergistic with NANO and Femtosecond Lasers**
- **Tailoring/Utilization of (mainly two-state) “Quantum States” - electron or nuclear spin/energy level, Photon polarization/spin, Super conduction charge number/phase (Qubits - Quantum bits)**
- **Especial Technological interest in Revolutionary capabilities derived from Quantum Entanglement (Produces/exhibits non-classical, non-intuitive, NON-LOCAL behavior).**
- **Entanglement defined as highly correlated Quantum states. If entangled material is separated spatially a change in one portion INSTANTANEOUSLY changes the other portion irrespective of distance.**

Quantum Technology Arenas

- **Zero Point Energy**
- **Cryptography keyes**
- **Materials (nano at the quantum limit, magnetics)**
- **Sensors (including Quantum well Infrared detectors)**
- **Computing (Progressing very rapidly, petaflops and beyond)**
- **Imaging (“interaction free,” Quantum holography,)**
- **Information Systems**
- **Communications (Instantaneous irrespective of distance, usefulness TBD)**
- **Optical Systems (e.g. Quantum Interferometry)**
- **“Electronics”**

Quantum Effects in the Macro/Classical World

- **Lasers**
- **Bose-Einstein Condensate**
- **Super-Fluidity**
- **Super-Conductivity**
- **Quantum Entanglement**
- **Fermionic Condensate**
- **Quantum Magnetic Deflagration**

ACCESS TO SPACE
THE (USUAL) DESIGN OPTIONS

- **Rockets (various)**
- **Airbreathing (various)**
- **Staging (single, two, three, etc.)**
- **Reusable/expendable**
- **Horizontal/vertical T/O and landing**
- **Fuels (various)**
- **Manned/unmanned**
- **Materials (various)**
- **Controls (various)**

Thus far--no clear "winning combinations" for either affordability or flexibility metrics, are agonizing along evolutionary development paths, worldwide

Revolutionary Rocket Technologies

- Propulsion Cycle:

a) PDWR - order[s] of magnitude reduction in turbine feed pump pressure [huge cost /reliability payoff],Deton. In Liquid Fuel

b) Base Region Augmentor - “poor man’s Airbreather’,use hypermixing to entrain external air,triples thrust/doubles payload

- Fuels - HEDM [e.g.Cubanes/N4,atomic C/H…],Isomers,Anti-matter,H-B-11 Fusion
- Materials - SWCNT,NNT,Micro-structured Materials,Amorphous metals,free-form Fabrication

Revolutionary rocket Technologies - Continued

- “Designer Aero’ - “Flow Control”,obviate “Ballast/packaging problems” & obviate shock Drag [forward liquid injection]
- Launch Assist:

a) Beamed MW’s from ground to Rectennas on side of bird,Energy powers base region MHD Accelerator,enables 2500 Sec. Of Isp

b) Polymer-stabilized/laser guided high Pressure Water Jets

c) Tidmans “Slingatron”

d) Tethers

An Approach to Orders of Magnitude Reductions in Weight/Cost of Exploration “Upmass” to LEO

- **Collect/Pressurize in-space “Propellant Mass” [not fuel] from “upper Atmosphere”,re-use collected disassociation energy**
- **Utilize an in-orbit “Beamer” [space infrastructure/utility] , transfer collected energy to the vehicle [MW’s/Rectennas,Lasers/PV]**
- **High Thrust/High g acceleration in near[er] field of the beamer out of the Gravity well using MHD accelerator with Isp ~ 2000 seconds**

Possible MHD Synergisms

- **MHD Accelerator:**
  - **In-space Propul. via Beamers**
  - **“Launch Assist” via Ground-based Beamers**
- **MHD Generator:**
  - **Regenerative Aerobraking**

[Sampling of] HEDM Candidates

- **SBER**
- **Metallic H2**
- **Solid H2 with Atomic C/B/H**
- **Cubanes/N4**
- **Metastable He**
- **Positrons/Anti-matter**
- **Quantum Nucleonics [Isomers]**
- **H/B-11 Fusion**

Aneutronic H-B11 Fusion

Inertial Electrostatic Confinement Fusion [QED,IEC,IEF]

- **Produces Protons,Direct MHD Electricity Generation vice [Neutron] Thermalization**
- **Reduced Radiation Hazard[s]/Weight**
- **High Thrust-to-weight AND High Isp [via reduced - shielding,magnetics,High Power Drivers]**
- **For SSTO,Payload Mass Fraction is ~ 14%,Launch Cost Estimate ~ $100/lb**

Nominal Power Densities

- **ZPE……..E108 X Chemical**
- **Anti-Matter/Positrons….. E10 X Chemical**
- **Fission/Fusion…….. E6 X Chemical**
- **Isomers……. E5 X Chemical**
- **SBER…… E2 X Chemical**
- **Hydrogen……..……..38 KWH/Kg**
- **HC……..14 “**
- **Advanced Flywheels……. .9 - 20? “**
- **Batteries…….. ……. .04 - 10? “**
- **SMES…… .0015 - ~100? “**
- **Super/ultra Capacitors…… .0007 -8? “**

Energetics “Wild Cards” Being Worked

- Solitons for Divergence Free Power Beaming
- Positron Storage as Positronium
- High Efficiency Plastic Nano PV
- 30%+ Thermo-Electrics
- High Efficiency [KW/KG] Fuel Cells
- “On-Site” H2 Generation vice Storage [Zinc,….]
- Room Temperature S-C
- Tapping ZPE
- Controlled Nuclear Isomer Release
- SMES with CNT Magnets
- Lithium Tantalate Crystals

Soliton Energy Transfer…..

- Solitons are waves in non-linear systems which are non-dispersive,”maintain amplitude”
- Utilized in optical communications [information transfer],up to 1,000,000 Km thus far
- Physics evidently allows utilization for Energy Transfer,Not yet accomplished

- Would change Energetics MUCH [DE weaponry, SPSats, Beamed Energy Propulsion,……]

“Sensors are poised on the Brink of a Revolution Similar to that experienced in Micro-Computers in the 1980’s”

Jon Wilson,2004
Editor-in-Chief,Sensor Technology Handbook

Sensor Trends

- **Mini-to-Micro-to-Nano**
- **Hyper-Spectral**
- **Multi-physics**
- **Hyper-Sensitive**
- **Hyper-Resolution**
- **Integrated with Actuators,Processors,Comms**
- **Sensor Webs/Swarms/”Net-works”**
- **Lower Power,Energy “Harvesting”**
- **Brilliant**
- **Ubiquitous**
- **Data Fusion/Sense-Making**
- **“Wireless”**
- **Apertures from Co-op conops ,Membranes**
- **Active and passive**

[Sample] Emerging Sensor Technology areas

- **Terrahertz**
- **Biomimetics,Bio [living] sensors**
- **Protein Engineering**
- **Femto-second Lasers**
- **CNT's [bio,chem]**
- **GPS as active sensor "Source"**
- **Infrasound**
- **Atmospheric static E Field**
- **Cadmium-Zinc-Telluride Gamma Ray Sensors**

The Sensor Capability Spiral

- **MEMS Technology enables ever smaller Sensors/Instruments which**
- **Reduces requisite energy/power and**
- **Improves sensor response and**
- **Increases sensitivity and also**
- **Reduces cost[s] thereby enabling**
- **Huge increases in sensor ubiquity/Networks [10,000….] and Resolution**

And Then There is NANO…..

Sample Nano-Sensor Frontier

- **Nano/RFID tags [w/138 digits ID every molecule on Planet,Japanese Children , Mexican Police & Hospitals/Walmart/ETC….]**
- **Smart dust[comms/sensors/PV - mm]**
- **Quantum entanglement-based sensor enhancements**
- **10^{-6} ^{o}F IR focal plane arrays (nanocantilevers)**
- **Single molecule detection,detection of single molecules**
- **F-sec laser induced signatures**
- **Atom optics/Matter wave sensors [E4-to-E6 improvements,esp. gyro/inertia Sensors]**
- **Nav via pulsing cosmic X-ray sources**

Sample Characteristics of Emerging Global Sensor Grid

- **Military,Commercial/Industrial,Public Safety,Scientific, Populace Contributions/Observations**
- **Ever-Improving Sensitivity,Resolution, Ubiquity, Connectivity,Fusion/"Sense-Making",Physical Phenomena "Coverage"**
- **Land,Sea,Air,Space,"Internal"/External**

……..

Capabilities Enabled by the On-Going Tech. Revolutions

- **GEO+ “Long Dwell” systems,<1m**
- **Miniaturized,affordable,ultrasensitive,ubiquitous,lightweight,Brilliant,low power Req.,ultraspectral,multiphysics,long-lived Multi-purpose/Reconfig. in-space “assets”**
- **Rapid/inexpensive reconstitution**
- **Huge Apertures [sparse arrays,membranes]**
- **Requisite Band widths**

12-turn Spiral,
Gyrating on a 3.0 m radius at 9 Hz

Femto/ATTO-Second Lasers

- **Order E-15 Pulse Length, a “scalpel”**
- **Improved Atmospheric Propogation (< breakdown time), “Pre-Plasma Channeling”/en-route amplification**
- **Can “cut through anything,” 100 Terrawatt to Petawatts per pulse**
- **Wholly new/different material Interactions/Kill Mechanisms, no “protective plasma layer” formation, Huge localized electrical/magnetic fields (>atomic forces)**
- **Can be small/inexpensive**

Femto/ATTO-Second Lasers Applications

- **Sensing**
- **Laser and (from “secondaries”) - gamma/x-ray (effective defense against hordes/swarms)**
- **Fission ignition (accomplished)**
- **Enables new neutron, positron, x-ray and gamma ray sources**
- **Fusion ignition/thermonuclear**
- **Broaching, “make safe”**
- **Comms**
- **Beamed propulsion**
- **Materials processing and “machining”**
- **Medical applications**

Defense Against Air/Space Borne Swarms via Femto-Second Lasers

- **Continuous/cued surveillance of Environs via f-second lasers to find/illuminate/induce "fluoresence" of swarm elements**
- **Attrition via f-second laser slewing/ kill mechanisms/X-rays, improved atmospheric propagation and amplification from "channeling" CW laser**

NOTE: The anticipated reduced thermal/other inertia of swarm components compared to 20th Century munitions facilitates "take down/out" via f-second lasers.

Sampling of "Interesting" Technology Capabilities

- Factor of 5-to-8 Dry Wt. Red.- CNT's
- E8 more in computing-nano/molec/quantum
- Tb+ Bandwidth - optical
- 30%+ direct Conversion - Thermal to Elec.
- 50%+ PV
- Storable Positrons - E9 Xchem.
- Gamma Ray Lasers - Positrons
- SMES at 3Xchem - CNT Magnets
- H-B11 Fusion - aneutronic/safe
- Miniaturized,ultra-sensitive,ubiquitous,low power,multi-physics Sensors

Tech. Sampling [Continued]

- Non-Cryo H2 Storage - Casimir Force designs
- Electron beam free form fabrication,Here & “There”
- Tethers for energy harvesting
- 300M to 1km + brilliant Membranes

Resulting Space System[s]

- Swarms of Miniaturized Payloads, resulting ubiquitous & inexpensive space access
- Huge apertures via smart membranes and Co-op conops - “Staring”
- Wonderous instrument etc. sensitivity , resolution, bandwidth
- Nav via Atom-optics,Pulsing cosmic X-Ray sources,optical GPS
- In-Space Beamers,Propulsion/orbit-raising and Ground/air/space Attack
- In-space fab/repair
- Monitoring of nano/RF tags, personal/onperson Electronics,wake vortices

In-Space Infrastructures?

- Fuel Depots,Tethers
- In-Situ Free Form fab & Repair/Service
- In-Space Beamers:

- Lasers [50% solid state/FEL],MW - 50+% Monochromatic PV,Revolutionary Rectennas,concentrators/lenses
- "Fueled",PV,Isomer or Nuc [various e.g.vortex],E-M Tethers
- Beamed energy for orbit raising,Maneuvering [Isp = 2500 /MHD,sails],Asteroid defense,space debris
- Atmospheric "dips" for "fuel"? [aerobrake maneuv.]
- Highly Vulnerable
- "Dual Use" [Civilian,Commercial,Space ops/Anti-space/Ground Attack…]

Satellite Outlook[s]

- [Continued] Extreme size Reductions via IT,Micro/Nano,Energetics Technology Revolutions
- Wonderous AFFORDABLE Enhanced Functionality across-the-board
- Aperture via Co-operative Con-ops or Membranes

Leading to/providing:

- "Everymans" Space capability [$50K fab & Launch,value/lb vice $/lb]
- Global Sensor Grid [Scientific/Commercial/Military]

Launch Vehicle Outlook[s]

- Reduced size/Multiple Payloads
- Automatic/autonomous ops [Reduced “standing Army Costs,IVHM]
- Reduced cost/Ruggedized “Conventional Rockets”
- Revolutionary Rockets [PDWR,Ejector,Beamed MWs/MHD,HEDM/Adv. Fuels,CNT Materials..]
- Micro/MEMS Rockets

Ongoing Changes/Options in Space Utilization & Economics

- From IT/Bio/Nano - Payloads which are much Smaller/Lighter/Smarter/Cheaper
- Results in increasing “Value per pound” and less pounds /costs for space access
- Decreasing rational for “Humans in Space” (Robotics MUCH “better/cheaper/faster”)
- Revol. Rocket & “Mass Launch” Options
- Reusable In-Space Infrastructures (Fuel Depots, “Beamers,” Insitu free form fab.)

And Then There Is "Near Space"

- **Nominally 75k ft to 325k ft**
- **FAR Cheaper, "Faster" [development/deployment] and "Better" [e.g. Resolution, Persistance] than [TAC] "Space"**
- **Buoyant Lift Problematical above ~ 90 k ft**
- **Fixed Wing[s] "work", KEY IS ENERGETICS/PROPULSION**

- Currently PV/Fuel Cells/Elec. Motors

- Future options include Positrons, SMES/CNT Magnetics, Soliton Energy Beaming, X10 improved Fuel Cells and X3 improved PV

Space Tech “Futures” Bottom Lines

- The ongoing IT/Nano/Energetics Tech Revolutions will Revolutionize SPACE Technology in terms of Capabilities/Size/Cost/Flexibility/Ubiquity
- There is an “Embarrassment of Riches” in terms of “Tech. Opportunities/options” with more added almost daily,needs to be Continuously Triaged - investigate 20 to get 2 or 3 really good ones [wide ranging metrics]
- World-Wide Technology/Capabilities

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